Programmer-defined Functions

Development of simple functions using value and reference parameters

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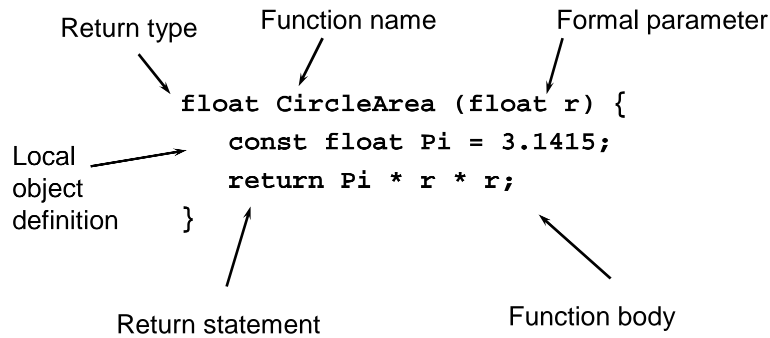
Function Definition

- Includes description of the interface and the function body
  - Interface
    - Similar to a function prototype, but parameters' names are required
  - Body
    - Statement list with curly braces that comprises its actions
    - Return statement to indicate value of invocation

Function Definition



Function Invocation

Actual parameter

```
cout << CircleArea(MyRadius) << endl;
```

To process the invocation, the function that contains the insertion statement is suspended and `CircleArea()` does its job. The insertion statement is then completed using the value supplied by `CircleArea()`.

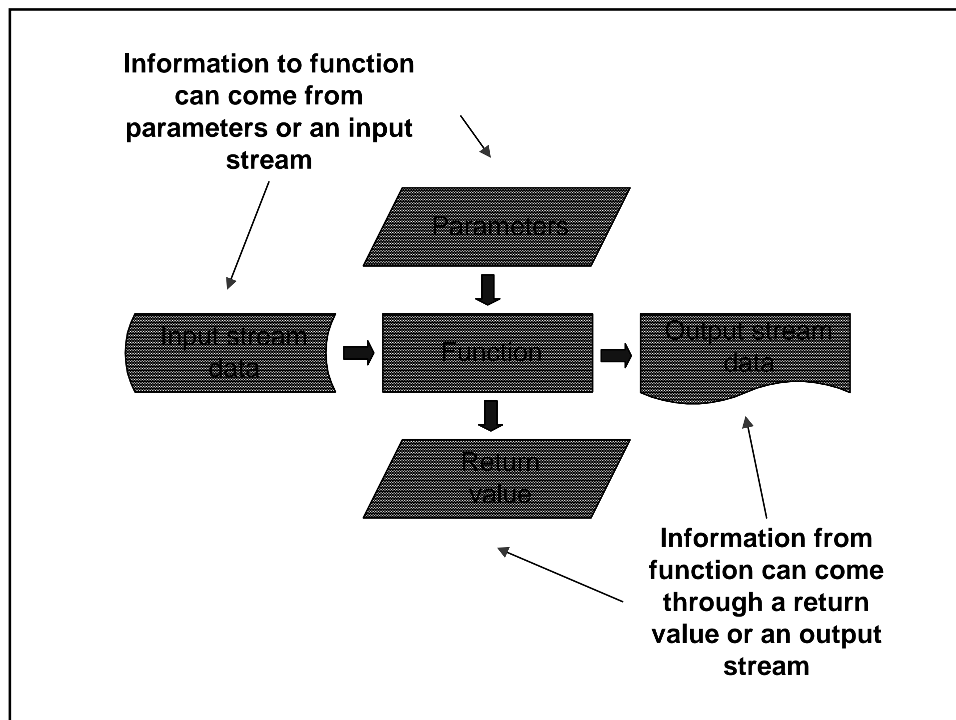
Simple Programs

- Single file
  - Include statements
  - Using statements
  - Function prototypes
  - Function definitions
- Functions use value parameter passing
  - Also known as pass by value or call by value
    - The actual parameter is evaluated and a copy is given to the invoked function

```
#include <iostream>
using namespace std;
float CircleArea(float r);
// main(): manage circle computation
int main() {
   cout << "Enter radius: ";
   float MyRadius;
   cin >> MyRadius;
   float Area = CircleArea(MyRadius);
   cout << "Circle has area " << Area;
   return 0;
}
// CircleArea(): compute area of radius r circle
float CircleArea(float r) {
   const float Pi = 3.1415;
   return Pi * r * r;
}
```

Value Parameter Rules

- Formal parameter is created on function invocation and it is initialized with the value of the actual parameter
- Changes to formal parameter do not affect actual parameter
- Reference to a formal parameter produces the value for it in the current activation record
- New activation record for every function invocation
- Formal parameter name is only known within its function
- Formal parameter ceases to exist when the function completes
- Activation record memory is automatically released at function completion



PromptAndRead()

```
// PromptAndRead(): prompt and extract next
// integer

int PromptAndRead() {
   cout << "Enter number (integer): ";
   int Response;
   cin >> Response;

   return Response;
}
```

Sum()

```
// Sum(): compute sum of integers in a ... b
int Sum(int a, int b) {
   int Total = 0;
   for (int i = a; i <= b; ++i) {
        Total += i;
   }
   return Total;
}
```

Problem

- Definition
  - Input two numbers that represent a range of integers and display the sum of the integers that lie in that range
- Design
  - Prompt user and read the first number
  - Prompt user and read the second number
  - Calculate the sum of integers in the range smaller...larger by adding in turn each integer in that range
  - Display the sum

Range.cpp

```
#include <iostream>
using namespace std;

int PromptAndRead();
int Sum(int a, int b);

int main() {
  int FirstNumber = PromptAndRead();
  int SecondNumber = PromptAndRead();
  int RangeSum = Sum(FirstNumber , SecondNumber);
  cout << "The sum from " << FirstNumber
    << " to " << SecondNumber
    << " is " << RangeSum << endl;
  return 0;
}
```

Range.cpp

```
// PromptAndRead(): prompt & extract next integer
int PromptAndRead() {
   cout << "Enter number (integer): ";
   int Response;
   cin >> Response;
   return Response;
}

// Sum(): compute sum of integers in a ... b
int Sum(int a, int b) {
   int Total = 0;
   for (int i = a; i <= b; ++i) {
        Total += i;
   }
   return Total;
}
```

Blocks and Local Scope

- A block is a list of statements within curly braces
- Blocks can be put anywhere a statement can be put
- Blocks within blocks are *nested* blocks
- An object name is known only within the block in which it is defined and in nested blocks of that block
- A parameter can be considered to be defined at the beginning of the block corresponding to the function body

Local Object Manipulation

```
void f() {
   int i = 1;
   cout << i << endl;          // insert 1
   {
      int j = 10;
      cout << i << j << endl;  // insert 1 10
      i = 2;
      cout << i << j << endl   // insert 2 10
   }
   cout << i << endl;          // insert 2
   cout << j << endl;          // illegal
}
```

Name Reuse

- If a nested block defines an object with the same name as enclosing block, the new definition is in effect in the nested block

However, Don't Do This At Home

```
void f() {
   {
      int i = 1;
      cout << i << endl;        // insert 1
      {
         cout << i << endl;    // insert 1
         char i = 'a';
         cout << i << endl;    // insert a
      }
      cout << i << endl;        // insert 1
   }
   cout << i << endl;           // illegal insert
}
```

Global Scope

- Objects not defined within a block are global objects
- A global object can be used by any function in the file that is defined after the global object
  - It is best to avoid programmer-defined global objects
    - Exceptions tend to be important constants
- Global objects with appropriate declarations can even be used in other program files
  - **`cout`**, **`cin`**, and **`cerr`** are global objects that are defined in by the iostream library
- Local objects can reuse a global object's name
  - Unary scope operator :: can provide access to global object even if name reuse has occurred

Don’t Do This At Home Either

```
int i = 1;
int main() {
    cout << i << endl;            // insert 1
    {
       char i = 'a';
       cout << i << endl;         // insert a
       ::i = 2;
       cout << i << endl;         // insert a
       cout << ::i << endl;       // insert 2
   }
   cout << i << endl;
    return 0;
}
```

Consider

```
int main() {
   int Number1 = PromptAndRead();
   int Number2 = PromptAndRead();
   if (Number1 > Number2) {
      Swap(Number1, Number2);
   }
   cout << "The numbers in sorted order:"
    << Number1 << ", " << Number2 << endl;
   return 0;
}
```

Using

```
void Swap(int a, int b) {
   int Temp = a;
   a = b;
   b = Temp;
   return;
}
```

Doesn't do what we want!

Consider

- A parameter passing style where
  - *Changes to the formal parameter change the actual parameter*

That would work!

Reference Parameters

- If the formal argument declaration is a *reference* parameter then
  - Formal parameter becomes an *alias* for the actual parameter
    - *Changes to the formal parameter change the actual parameter*
- Function definition determines whether a parameter's passing style is by value or by reference
  - Reference parameter form

$\texttt{ptype}_i$ $\texttt{\&pname}_i$

```
void Swap(int &a, int &b)
```

Reconsider

```
int main() {
  int Number1 = PromptAndRead();
  int Number2 = PromptAndRead();
  if (Number1 > Number2) {
      Swap(Number1, Number2);
  }
  cout << "The numbers in sorted order: "
   << Number1 << ", " << Number2 << endl;
  return 0;
}
```

Using

```
void Swap(int &a, int &b) {
  int Temp = a;
  a = b;
  b = Temp;
  return;
}
```

Passed by reference -- in an invocation the actual parameter is given rather than a copy

Return statement not necessary for void functions

Consider

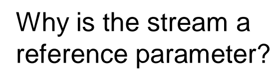
```
int i = 5;
int j = 6;
Swap(i, j);
int a = 7;
int b = 8;
Swap(b, a);
```

```
void Swap(int &a, int &b) {
  int Temp = a;
  a = b;
  b = Temp;
  return;
}
```

Extraction

- Function to extract a value from a given stream

```
void GetNumber(int &MyNumber, istream &sin) {
    sin >> MyNumber;
    return;
}
```



Getnum.cpp

```
int main() {
    ifstream fin("mydata.txt");
    int Number1;
    int Number2;
    cout << "Enter number: ";
    GetNumber(Number1, cin);
    // not needed: cout << "Enter number: ";
    GetNumber(Number2, fin);
    if (Number1 > Number2) {
        Swap(Number1, Number2);
    }
    cout << "The numbers in sorted order: "
     << Number1 << ", " << Number2 << endl;
    return 0;
}
```

Constant Parameters

- The `const` modifier can be applied to formal parameter declarations
  - `const` indicates that the function may not modify the parameter

```
void PromptAndGet(int &n, const string &s) {
   cout << s ;
   cin >> n ;
   // s = "Got it";      // illegal assignment
}                        // caught by compiler
```

  - Sample invocation

```
int x;
PromptAndGet(x, "Enter number (n): ");
```

Constant Parameters

- Usefulness
  - When we want to pass an object by reference, but we do not want to let the called function modify the object
- Question
  - Why not just pass the object by value?
- Answer
  - For large objects, making a copy of the object can be very inefficient

Passing Constant Rectangles

```
void DrawBoxes(const RectangleShape &R1,
 const RectangleShape &R2) {
   R1.Draw();
   R2.Draw();
}

int ApiMain() {
   SimpleWindow Demo("Demo Program");
   Demo.Open();
   RectangleShape Rect1(Demo, 3, 2, Blue);
   RectangleShape Rect2(Demo, 6, 5, Yellow);
   DrawBoxes(Rect1, Rect2);
   return 0;
}
```

Default Parameters

- Observations
  - Our functions up to this point required that we explicitly pass a value for each of the function parameters
  - It would be convenient to define functions that accept a varying number of parameters
- Default parameters
  - Allows programmer to define a default behavior
    - A value for a parameter can be implicitly passed
    - Reduces need for similar functions that differ only in the number of parameters accepted

Default Parameters

- If the formal argument declaration is of the form

  $\texttt{ptype}_i$ $\texttt{pname}_i$ = $\texttt{dvalue}_i$

- then
  - If there is no i^{th} argument in the function invocation, $\texttt{pname}_i$ is initialized to $\texttt{dvalue}_i$
  - The parameter $\texttt{pname}_i$ is an optional value parameter
    - Optional reference parameters are also permitted

Consider

```
void PrintChar(char c = '=', int n = 80) {
  for (int i = 0; i < n; ++i)
      cout << c;
}
```

- What happens in the following invocations?

```
PrintChar('*', 20);
PrintChar('-');
PrintChar();
```

Default Parameters

- Default parameters must appear after any mandatory parameters
- Bad example

```
void Trouble(int x = 5, double z, double y) {
   ...
}
```

Cannot come before mandatory parameters

Default Parameters

- Consider

```
bool GetNumber(int &n, istream &sin = cin) {
   return sin >> n ;
}
```

- Some possible invocations

```
int x, y, z;
ifstream fin("Data.txt");
GetNumber(x, cin);
GetNumber(y);
GetNumber(z, fin);
```

- Design your functions for ease and reuse!

Function Overloading

- A function name can be overloaded
  - Two functions with the same name but with different interfaces
    - Typically this means different formal parameter lists
      - Difference in number of parameters

        ```
        Min(a, b, c)
        Min(a, b)
        ```
      - Difference in types of parameters

        ```
        Min(10, 20)
        Min(4.4, 9.2)
        ```

Function Overloading

```
int Min(int a, int b) {
   cout << "Using int min()" << endl;
   if (a > b)
       return b;
   else
       return a;
}
double Min(double a, double b) {
   cout << "Using double min()" << endl;
   if (a > b)
       return b;
   else
       return a;
}
```

Function Overloading

```
int main() {
  int a = 10;
  int b = 20;
  double x = 4.4;
  double y = 9.2;
  int c = Min(a, b);
  cout << "c is " << c << endl;
  int z = Min(x, y);
  cout << "z is " << z << endl;
  return 0;
}
```

Function Overloading

- Compiler uses function overload resolution to call the most appropriate function
  - First looks for a function definition where the formal and actual parameters exactly match
  - If there is no exact match, the compiler will attempt to cast the actual parameters to ones used by an appropriate function
- The rules for function definition overloading are very complicated
  - Advice
    - Be very careful when using this feature

Random Numbers

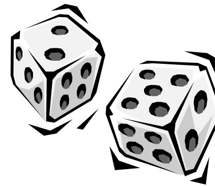
- Generating a sequence of random numbers is often useful
  - In a game, it ensures that a player does not see the same behavior each time
  - In a simulation of a complex system, random numbers can be used to help generate random events
    - Car crash in a simulation of a highway system
    - Likelihood of a gene in cell mutation
    - Weather simulation

Uniform Random Numbers

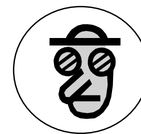
- Uniform random number sequence
  - A sequence of random numbers where
    - Each value in the sequence is drawn from the same range of numbers
    - In each position of the sequence, any value in the number range is equally likely to occur

Random Numbers

- Examples
  - Generate a uniform random number sequence in the range 1 to 6
    - Use a fair six-sided die
    - Each roll represents a new random number

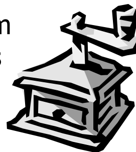


  - Generate a uniform random number sequence in the range 1 to 2
    - Use a fair coin
      - Heads: 1, Tails: 2



Random Numbers

- We can write an algorithm for generating what looks like random numbers



30 21 9 28 29 ...

- Because it's an algorithm, we know the rules for generating the next number
  - The generated numbers are not really random
    - They are properly called pseudorandom numbers

Stdlib Library

- Provides in part functions for generating pseudorandom numbers
  - `rand()`
    - Returns a uniform pseudorandom unsigned int from the inclusive interval 0 to **`RAND_MAX`**

```
#include <iostream>
#include <string>
#include <cstdlib>
using namespace std;
int main() {
   for (int i = 1; i <= 5; ++i)
      cout << rand() << endl;
   return 0;
}
```

Different Sequences

- To produce a different sequence, invoke

```
void srand(unsigned int);
```

- Consider seed.cpp

```
int main() {
   cout << "Enter a seed: ";
   unsigned int Seed;
   cin >> Seed;
   srand(Seed);
   for (int i = 1; i <= 5; ++i)
      cout << rand() << endl;
   return 0;
}
```

Different Sequences

- To automatically get a different sequence each time
  - Need a method of setting the seed to a random value
    - The standard method is to use the computer's clock as the value of the seed
    - The function invocation **`time()`** can be used
      - Returns an integral value of type **`time_t`**
      - Invocation **`time(0)`** returns a suitable value for generating a random sequence

Randseed.cpp

```
#include <iostream>
#include <string>
#include <cstdlib>
#include <ctime>
using namespace std;

int main() {
   srand((unsigned int) time(0));
   for (int i = 1; i <= 5; ++i)
      cout << rand() << endl;
   return 0;
}
```

Recursion

- Recursion is the ability of a function to call itself.
- Consider the mathematical function n!

  $n! = n * (n-1) \ldots * 2 * 1$

  is not mathematically precise because we use an ellipsis (…).
- Consider the following formal definition
  - $n! = 0$, if $n = 0$
  - $n! = n * (n-1)!$, if $n > 0$
    - The factorial function is defined in terms of itself

Consider

```
#include <iostream>
#include <string>
using namespace std;
int main() {
  cout << "Enter a positive integer: ";
  int n;
  cin >> n;
  cout << n << "! = " << Factorial(n) << endl;
  return 0;
}
```

Using

```
int Factorial(int n) {
   if (n == 0) {
     return 1;
   }
   else {
     return n * Factorial(n-1);
   }
}
```

- C++ function mirrors the mathematical factorial definition
  - If the value of **n** is 0, the value 1 is returned.
  - Otherwise, the product of **n** and **Factorial(n-1)** is returned.

Recursion Visualization

- Consider **cout << n ! = " << Factorial(3) << endl;**